Microwave Holography of DSN Reflector Antennas

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The Microwave antenna holography imaging technique has progressed considerably in recent years. The technique has been successfully used for diagnostics, analysis, and performance improvement of most of the NASA/JPL Deep Space Network (DSN) large reflector antennas, especially at the shorter wavelengths. The JPL Microwave Antenna Holography System (MAHST) enables high resolution and high precision antenna imaging with a standard deviation of 100-nlicron. The pane] setting / unbending screw adjustment is provided with an accuracy of 1 O-20-microns. The holography technique has proven to be the least expensive method for increasing the link performance of the DSN ground antennas. The MAHST provides an efficient and low cost technique to optimize and maintain the performance of large earth station antennas, helping to fulfill today's requirements for ever increasing link performance. The system samples the far-field amplitude and phase pattern with a 90-dB dynamic range. A fast subreflector position optimization is provided which further increases the antenna performance. Other outputs of the system are aperture amplitude and phase functions, gravity deformation characterization and analysis, as well as directivity computations at other frequencies. The JPL MAHST is a portable system that can be shipped to any DSN antenna in the world and easily interfaced with its encoders and antenna drive systems. The MAHST was designed utilizing many "off the shelf" commercially available components. The remaining parts were designed and built at JPL. The MAHST has been successfully tested and demonstrated in the NASA / JPL DSN.

The holographic metrology technique utilizes the Fourier Transform relationship between the complex far-field radiation pattern of an antenna and its complex aperture distribution. The resulting aperture phase and amplitude distribution information is used to precisely characterize various crucial performance parameters, including panel alignment, subreflector position, antenna aperture illumination, directivity at various frequencies, and gravity deformation effects. Application of the MAHST information provides improved performance to the antenna that increases its signal to noise ratio (SNR) and therefore its channel capacity or information processing rate. Strong (continuous Wave (CW) signals obtained from geostationary satellite beacons are utilized as far-field sources. These strong CW beacon signals are available on many satellites at Ku-band, X-band, C-band, and S-band. A portable 2.8-meter antenna is used to provide the phase reference signal to the receiver phase lock loop (PLL) channel, The IF section consists of a Hewlett Packard Microwave Receiver (HP8530A) and an external PLL that enables amplitude and phase measurements of the ground antenna sidelobes with a 90-dB dynamic range. The far-field data is collected by continuously scanning, on a two-dimensional grid, the antenna being measured against a signal from a geosynchronous satellite. The angular extent of the data required is inversely proportional to the size of the desired resolution cell in the processed holographic maps and to the measurement frequency, The information in the surface error map is then used to compute the adjustments of the individual panels in an overall main reflector best-fit reference. frame. The amplitude map provides valuable information about the energy distribution in the antenna aperture.

Recent results of utilizing the MAHST in the NASA/JPL DSN will be presented;

(1) The MAHST was used to set the newly built 1> SS-24, 34-meter BWG antenna to 0.25-mm (infinite resolution axial error), making it the highest precision instrument in the NASA/JPL DSN. The precision of 1) S-24, $1.36*10^5$ (diameter/rms), was achieved with a single iteration of panel setting. By setting the panels and correcting the subreflector position, the MAHST improved the performance of DSS-24 by 5.0-dB at Ka-band (32-GHz) and 0.35-dB at X-band (8.45 -GHz) relative to its initial theodolite condition. The achieved peak efficiency of 1> SS-24, at 45-degrees elevation is 60.6% at Ka-band (32-GHz).

(2) Microwave Holography application applied to antenna gravity deformation:

(a) Will show how the information obtained from MAHST data was utilized for designing, fabricating and calibrating a prototype deformable flat-plate that compensates for the gravity deformation of a 34-meter BWG antenna. The resulting improvement at 12.7-degrees elevation is 1.73-dB at Ka-band (32-GHz).

(b) Will show how gravity deformation characterization by holography lead to an improved gravity deformation design of future DSN antennas.

(c) Will show how a low cost device suggested by Dr. Roy Levy of JPL has resulted in significant gravity performance improvement of the DSS-13 34-meter BWG antenna. An improvement of 1.14-dB at Ka-band (32-GHz) was inferred from holographic measurements at 12.7-degrees elevation,

(3) Utilizing the MAHST information to unbend the panels of 1)SS-13 antenna thereby improving its rms surface error from 0.38-mm to 0.31 -mm. Since DSS-13 was commissioned in 1990, microwave holography has improved its performance by 5.25-dB at Ka-band (32-G] lz). Microwave holography has enabled radio science observations to 49-GHz at 1> SS-13.